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Notes on the interspecific relationship in the genus *Rodgersia* (Saxifragaceae)

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ヤグルマソウ属数種の種間関係について

The genus *Rodgersia* A. Gray, consisting of six species, ranges from Japan to east Himalaya through SW China (Cullen 1975). Engler (1930) treated *Rodgersia* in the subtribe Astilbinae of the tribe Saxifrageae in the subfamily Saxifragoideae with *Astilbe* Buch.-Ham. ex D. Don and *Astilboides* Engl. *Rodgersia* is considered to be in much close relation with *Astilboides* and separated from *Astilbe* especially in leaf division and texture. However, it needs to study the relationship between *Rodgersia* and some genera such as *Oresitrophe* Bunge.

Cullen (1975) adopted the nature and presence of hairs, the shape, incision and arrangement of leaflets, the relative length of sepals, stamens, and styles, the accrescent nature of sepals after anthesis as diagnostic characters distinguishing each species of *Rodgersia* and revised with a key to all known species. However, the interspecific relationship has not yet been studied. This paper aims to provide several data for consideration to the relationship.

Materials and methods We examined the flowers and vegetative features using herbarium specimens. The seed was observed with a Hitachi S-700 scanning electron microscope (SEM) at 5 kV. Samples taken from herbarium specimens were mounted on stubs with alminium and coated with gold-palladium in an Eiko IB5 sputter coater. The materials for cytological observation were collected in 1987 in Yunnan, China. The root-tips used for cytological observations were fixed in the field. The pretreatment was made with 0.05% colchicine solution for about 3 hr at 5–15°C. After pretreatment, the root-tips were fixed

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with Newcomer's fluid. The maceration and staining of the root-tips were carried out simultaneously in mixed solutions of 9:1 2% acetic-orcein and 1N-HCl for about 24 hr and then squashed. Pollen grains were stained with cotton blue in lactophenol and measured under a microscope.

Observation and discussion Arrangement of leaflets. *Rodgersia* is diversified greatly in the arrangement of leaflets or foliolation. The species can be classified in three groups by the foliolation. *R. pinnata* Franch. is a group with 'quasi-digitate' pattern (Henry 1902) ; *R. aesculifolia* Batalin, *R. henricii* Franch., *R. podophylla* A. Gray are with digitate pattern; and *R. nepalensis* T. A. Cope

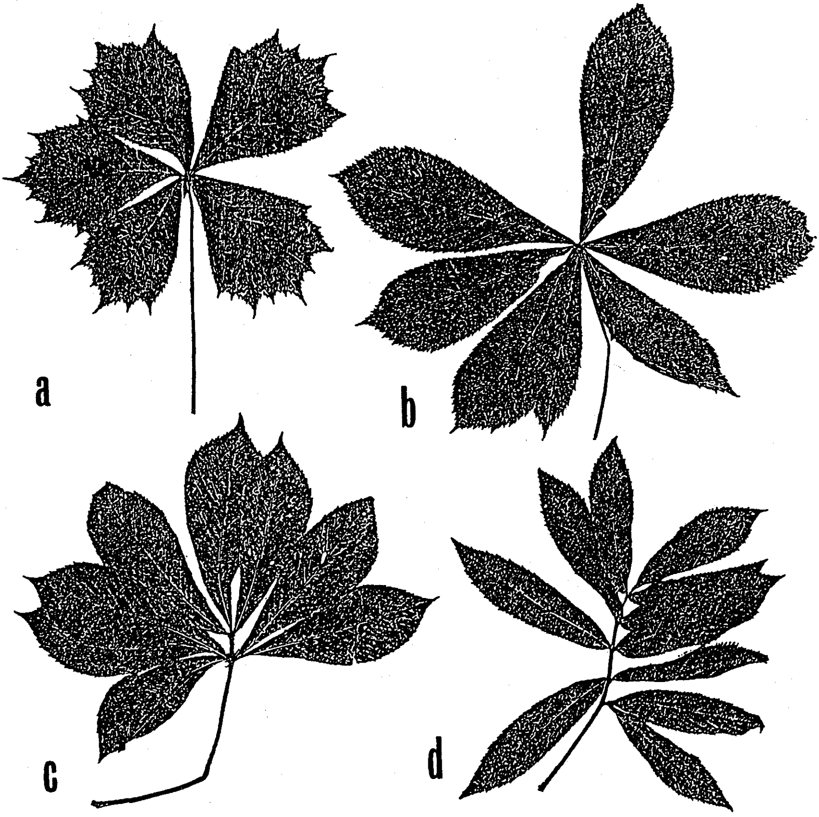


Fig. 1. The variation of leaves of *Rodgersia*. a. *R. podophylla*. b. *R. aesculifolia*. c. *R. pinnata*. d. *R. sambucifolia*. All ×0.2. [a. Japan. Yamanashi, Shimobe-cho. Kadota 2424, TI. b. China. Szechuan. Henry 7511, TI. c. China. Yunnan, Dali, Dianchang shan. Kato et al. 242, TI. d. China. Yunnan, Kunmin, near Hua-ji-gou. Murata & Yamazaki 9309, TI.]

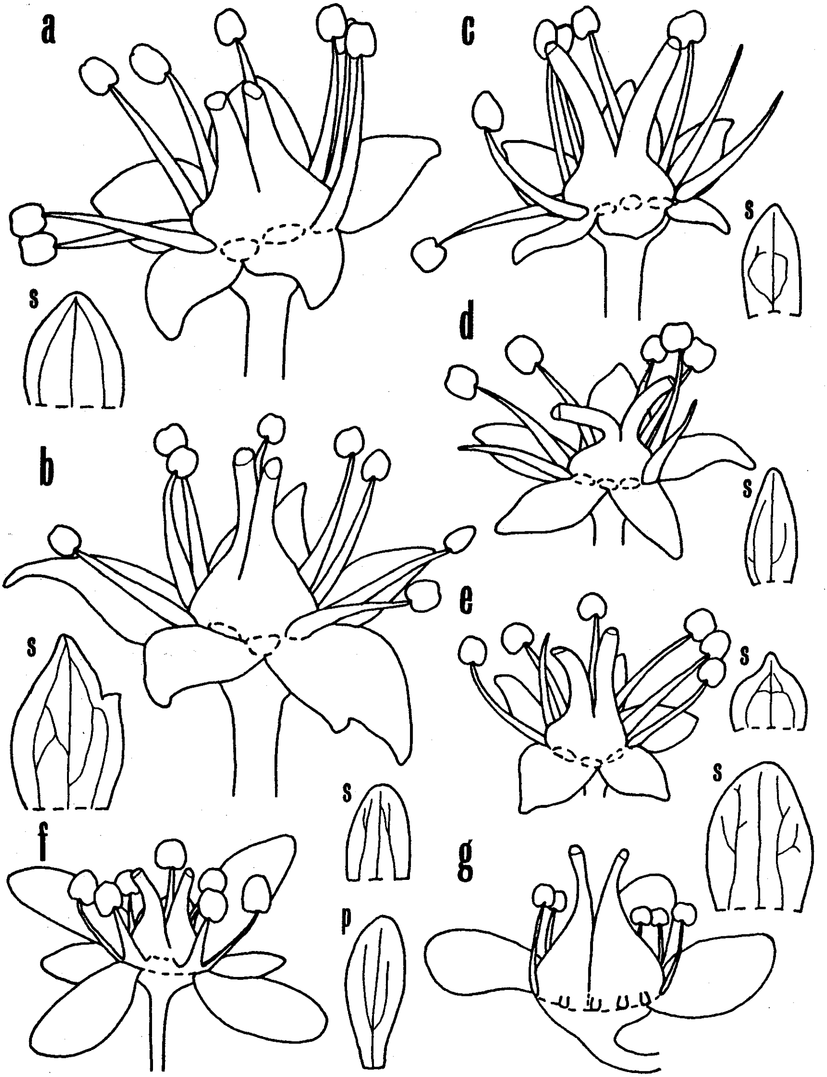


Fig. 2. Flowers, sepals (s) and petal (p) of *Rodgersia*, *Astilboides*, and *Oresitrophe*. Some sepals and anthers of flowers are removed. a. *R. pinnata*. b. *R. sambucifolia*. c & d. *R. podophylla*. e. *R. aesculifolia*. f. *Astilboides tabularis*. g. *Oresitrophe rupifraga*. All ×6. [a. China. Yunnan. Dali, Dianchang shan. Kato et al. 242, TI. b. China. Yunnan, Lijiang, Sandawan. Kato et al. 1818, TI. c. Korea. Kangwon-do, Sulak-san—Sinhung-sa. Murata & Ko 21129, TI. d. Japan. Nagano, Otari-mura. Yahara et al. 7193, TI. e. China. Szuchwan. Henry 5711, TI. f. N Korea. Komarov 814, TI. g. China. Kwangchow, Wulingshan. Chow 82006, TI.]

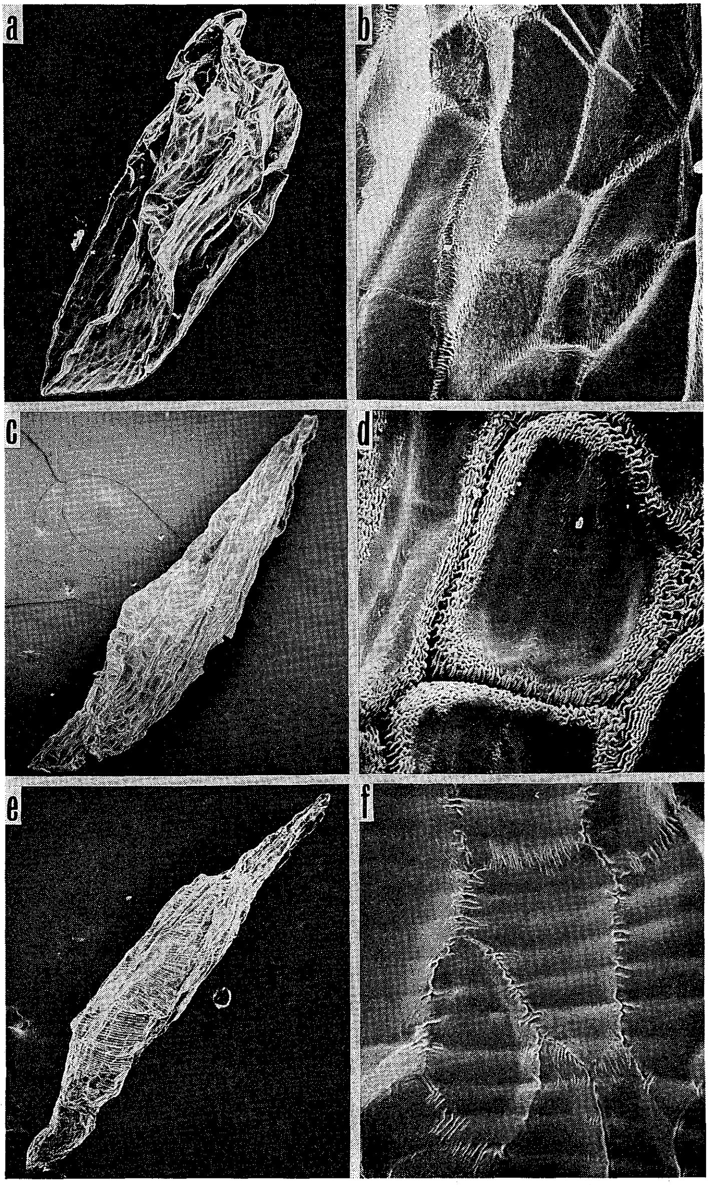
ex Cullen, *R. sambucifolia* Hemsl. are with pinnate pattern (Fig. 1). However, in some cases the well developed radical leaves of *R. sambucifolia* are hardly distinguishable from the normally foliolated leaves of *R. pinnata*, and those of *R. pinnata* resemble the digitate leaves of *R. aesculifolia*.

Flowers. Cullen (1975) did not mention the presence of petal at all. But, Engler (1930) wrote: "Pet. [=Petalen] meist nur 1-2 (selten 5), haufig 0". In our observations no petal is found in *R. podophylla*, *R. pinnata*, *R. sambucifolia* and *R. aesculifolia*. If petal exists in *Rodgersia*, it is thought as rudimental. In *R. sambucifolia* the sepals sometimes have a few triangular-shaped teeth. The stamens are arranged in two circles and those of the outer circle are alternate to sepals. The species of *Rodgersia* can not be distinguished by any single character or combination of characters, but the flowers of *R. pinnata* and *R. sambucifolia* are larger than those of *R. podophylla* and *R. aesculifolia* (Fig. 2).

The flowers of *Rodgersia* have 5 or rarely 6 sepals, 10 or rarely 12 stamens with basifixed anthers and slightly inferior bicarpellary, syncarpous ovaries with 2 styles. The apetalous nature is one of the diagnostic characters distinguishing *Rodgersia* from *Astilboides* with four distinct petals (Fig. 2f). A remarkable feature of *Astilboides* is the stamens which unite basally with each other. *Oresitrophe* has also apetalous flowers (Fig. 2g).

Seeds. The seeds of *R. sambucifolia* are approximately 1 mm long and elliptic-cylindrical (Fig. 3a), while those of *R. pinnata* and *R. podophylla* are 2–2.3 mm in length and linear-spindle in shape (Fig. 3c & e). The testa consists of more or less angular cells, of which the margin is fine lineate marked with fine short, hair-like ribs (Fig. 3b, d & f). In mature stage the testa surface is entirely covered with these ribs in *R. pinnata* and *R. sambucifolia* as well as *R. podophylla*, but gradually the ribs disappeared. The seeds of *R. podophylla* are transversely and prominently striate with fine narrow parallel striae (Fig. 3e & f). The seeds of *Astilboides* are not different from those of *Rodgersia* (Fig. 3g & h). The testa of the mature seeds is smooth except the marginal portion of each cell.

Chromosomes. The chromosome number of *Rodgersia* were reported by several authors, but the karyomorphological analysis has not yet been reported. Chromosome numbers which were reported by previous workers and the present study are shown in Tab. 1.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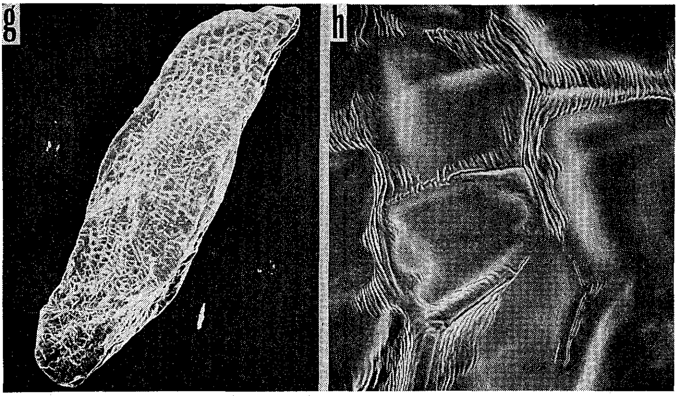

Fig. 3. Seeds of *Rodgersia* and *Astilboides*. a & b. *R. sambucifolia*. c & d. *R. pinnata*. e & f. *R. podophylla*. g & h. *Astilboides tabularis*. a×ca. 50, c, e & g×ca. 30, others×ca. 500. [a, b. China. Yunnan, Kunmin, near Hua-ji-gou. Murata & Yamazaki 9309, TI. c, d. China. Yunnan, Dali, Huadianba. Iwatsuki et al. 1567, TI. e, f. Japan. Kanagawa, Tanzawa, Oomuroyama. Midorikawa 1834, TI. g, h. China. See Chyun Dang. Mills 593, TI.]

Tab. 1. Chromosome numbers of *Rodgersia*.

Species	Chromosome numbers (n)	(2n)	Reference (Voucher specimen)
R. podophylla	15		Skovsted (1934)
		30	Hamel (1949)
		28	Lee (1969)
		30, 45	Funamoto & Tanaka (1983)
		30	Present study (Wakabayashi 90260, MAK)
R. pinnata		60	Hamel (1949)
		60	Present study (Iwatsuki et al. 591, TI)
		ca. 75	Present study (Ohba et al. 476, TI)
R. sambucifolia	30		Hamel (1949)

$2n=30$ chromosomes were observed in *R. podophylla* (Fig. 4c). The chromosomes in a complement varied gradually from 2.7 to 1.2 μm long. The karyotype (Fig. 5A) is composed of 13 pairs of m and sm chromosomes (nos. 1-13) and two pairs of st chromosomes (nos. 14-15). These two st pairs are nearly

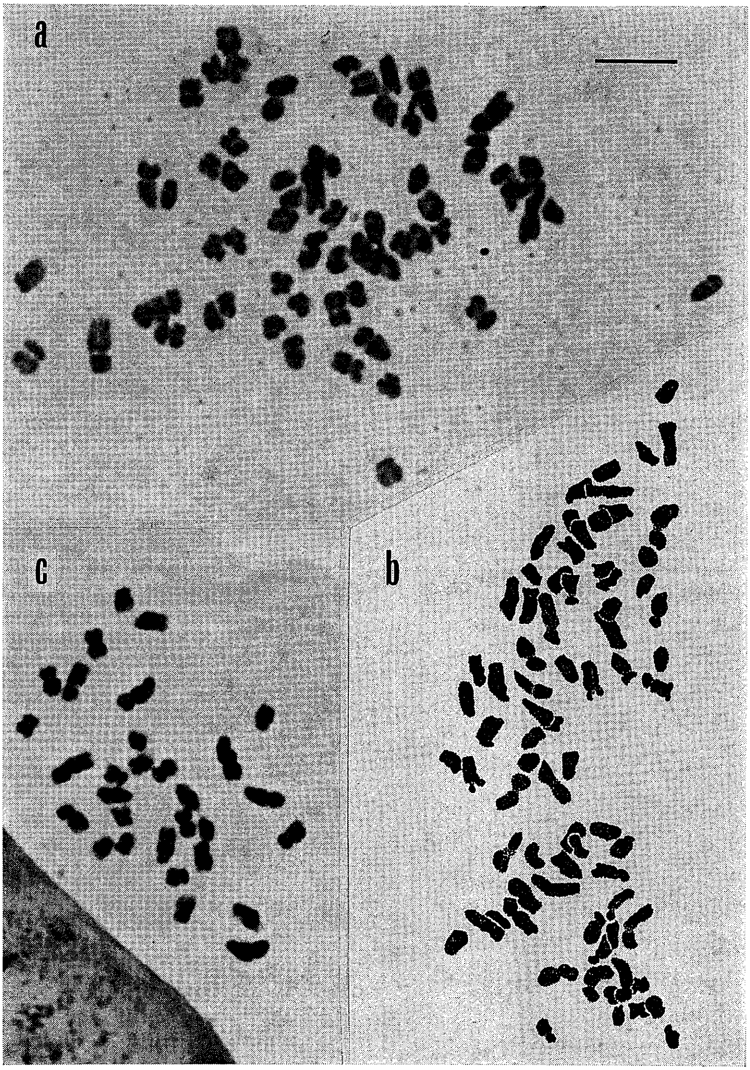

Fig. 4. Chromosomes of *Rodgersia*. a. *R. pinnata*, 2n=60. b. *R.pinnata*, 2n=ca. 75. c. *R. podophylla*,. 2n=30. Bar: 5 μm. [a. China. Yunnan, Lijiang, Dongshan. Iwatsuki et al. 591, TI. b. China. Yunnan, Lijiang, Ganhaizi. Ohba et al. 476, TI. c. Japan. Tokyo, Nishitama-gun, Mt. Mitoo-san. Wakabayashi 90260, MAK.]

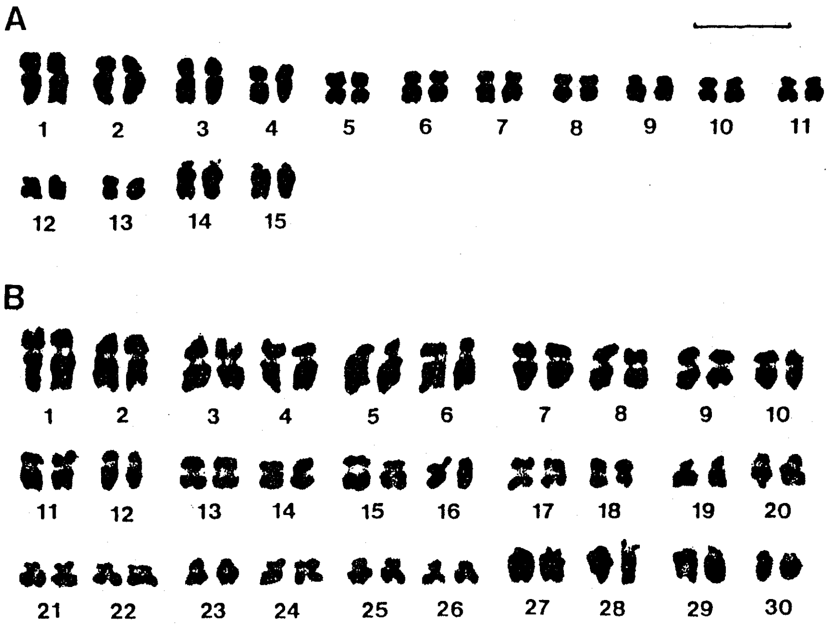

Fig. 5. Karyotypes of *Rodgersia*. A. *R. podophylla*, 2n=30. B. *R. pinnata*, 2n=60. Bar: 5 μm.

Tab. 2. Size of pollen grains of the species of *Rodgersia*.

Species	Polar diameter[1) (μm)	Estimated volume[2) (μm³)	Voucher specimen
R. podophylla	14.1±1.0	1480	Yahara et al. 7193, TI
	14.7±0.6	1680	Hara & Kurosawa s.n., TI
	14.5±0.6	1590	Togashi s.n., TI
R. aesculifolia	14.8±0.7	1720	Henry 5711, TI
R. pinnata	17.8±0.6	2960	Kato et al. 242, TI
	18.7±1.0	3440	Bartholomew et al. 318, TI
R. sambucifolia	18.9±1.0	3570	Kato et al. 1818, TI
R. nepalensis	22.1±0.9	5680	McCosh 391, TI

1) Average of 30 pollen grains.

2) Calculated from the average diameters by regarding the grains as spherical.

the same size and shape.

2n=60 and ca. 75 chromosomes were observed in *R. pinnata* (Fig. 4a & b). As those of *R. podophylla* the size of the chromosomes shows gradual change in a complement. The karyotype of 2n=60 is composed of 26 pairs of m and sm (nos. 1-26) and 4 pairs of st chromosomes (nos. 27-30) (Fig. 5B). The karyotype is similar to that of doubling of the chromosomal set of *R. podophylla*, but one pair of st chromosomes (no. 30) is smaller than the others.

The size of pollen grains. The size of pollen grains of *Rodgersia* is shown in Tab. 2. The average size varies from 14.1 μm of *R. podophylla* to 22.1 μm of *R. nepalensis*. The estimated volume of the grains of tetraploid species, *R. pinnata* and *R. sambucifolia*, is approximately two times larger than that of a diploid species, *R. podophylla*. In *R. aesculifolia* the volume is nearly as same as that of *R. podophylla* while that of *R. nepalensis* is 3.6 times larger than that.

General discussion The geographical pattern of each species is shown in Fig. 6. It is noticeable that the outline area of the genus *Rodgersia* coincides with the Sino-Japanese floristic region with some extention to the West and Central Asian floristic region (Good 1974). Four of all the six species are sympatrically distributed in SW China, and the range of *R. nepalensis* is allopatric as well as that of *R. podophylla*. SW China is regarded as a centre of the present distribution of *Rodgersia*.

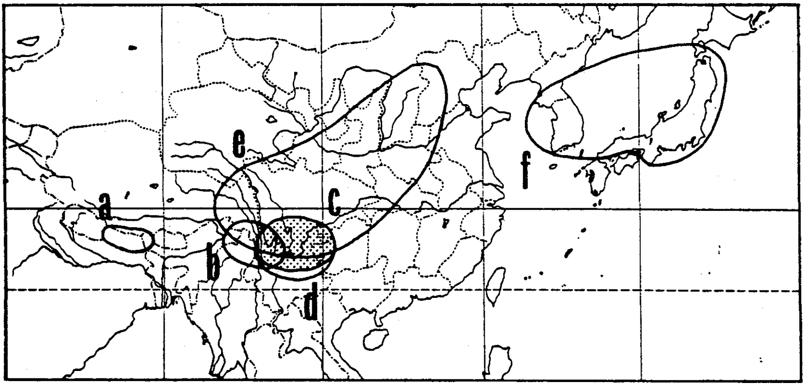

Fig. 6. Outline areas of each species of *Rodgersia*. a. *R. nepalensis*. b. *R. henricii*. c(dotted). *R. sambucifolia*. d. *R. pinnata*. e. *R. aesculifolia*. f. *R. podophylla*.

Morphologically *Rodgersia* is greatly diversified only in the foliolation. Except for the size of pollen grains no conspicuous difference is found in their flowers and fruits among species. Therefore, specimens without either radical or cauline leaves can not be determined. *Rodgersia* is classified in three groups using the differences in the foliolation, that is, the 'quasi-digitate' group represented by *R. pinnata*; the digitate group consisting of *R. aesculifolia, R. henricii, R. podophylla*; and the pinnate group of *R. nepalensis, R. sambucifolia*. It is remarkable that the four species of SW China spread over the three groups. *R. nepalensis* distributed in the west of SW China is the pinnate group and *R. podophylla* in the east of SW China is digitate group (Fig. 6). The 'quasi-digitate' pattern of *R. pinnata* is considered to be a transitional pattern between digitate and pinnate patterns.

Pinnate arrangement of leaflets is rare not only in the tribe Saxifrageae but also in the family Saxifragaceae. Even in *Astilbe*, the first division of leaves is not pinnate but ternate. It suggests that the species with 'quasi-digitate' or pinnate leaves might be more specialized than those with digitate ones in *Rodgersia*.

As shown in Tab. 1 the species of *Rodgersia* have been studied cytologically by several workers (Skovsted 1934, Hamel 1949, 1953, Lee 1969, Funamoto & Tanaka 1983). The chromosome numbers are reported from three species, i.e. $2n=30$, 45 in *R. podophylla* and $2n=60$ from *R. pinnata* and *R. sambucifolia*, while no chromosome number is known from the other three species. In this study $2n=60$ and ca. 75 are found in *R. pinnata*. This species is considered basically tetraploid (4x). *R. podophylla* with $2n=30$ is diploid. From the karyotype data *R. pinnata* is thought to be closely related to *R. podophylla*. But the tetraploid *R. pinnata* is considered to be somewhat diploidized because one pair of st chromosomes is smaller than the others. The volume of the pollen grains in the tetraploid species, *R. pinnata* and *R. sambucifolia*, was approximately two times larger than that of the diploid *R. podophylla*. This suggests that the polyploidy accompanies the volume increase of pollen grains. According to this suggestion *R. aesculifolia* is thought as diploid and *R. nepalensis* hexaploid or octaploid (Tab. 2). If so, the digitate group might be diploid while the other two groups polyploid. As conclusion these data support that *R. podophylla*, distributed in the easternmost of the total range of the genus, can be regarded as most primitive, while *R. nepalensis* distributed in the westernmost is regarded as most advanced. In *Astilboides* $2n=34$ chromosome numbers are reported (Hamel 1949). Cytologically *Astilboides* with $x=17$ basic number differs greatly from *Rodgersia* with $x=15$.

Literature cited

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ユキノシタ科ヤグルマソウ属は日本から東ヒマラヤにかけて6種があり，そのうち4種が中国西南部に同所的に分布する。外部形態，染色体，花粉を調べ，地理分布を含め，その系統関係について考察した。ヤグルマソウ属全体の分布域の最東に分布するヤグルマソウは，掌状複葉を有し，$2n=30$ の2倍体である。中国に分布する *Rodgersia aesculifolia* も掌状複葉を有し，花粉の大きさから2倍体と考えられる。中国西南部に分布する *R. pinnata* は，偽掌状複葉を有し，$2n=60$ の4倍体であり，*R. sambucifolia* は羽状複葉を有し，4倍体である。分布域の最西に分布する *R. nepalensis* は，羽状複葉を有し，花粉の大きさから6倍体ないしは8倍体である可能性が考えられる。外部形態，染色体等のデータから，ヤグルマソウは最も原始的であり，*R. nepalensis* は最も派生的であると推定された。